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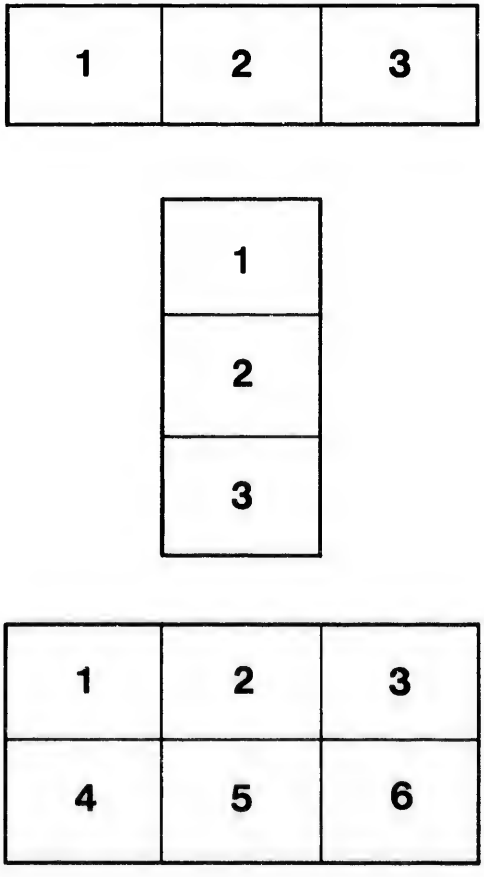

THE

GEOLOGICAL HISTORY

OF

LAKE SUPERIOR

BY

DR. ROBERT BELL, F.R.S.

(Read before the Canadian Institute, Toronto, April 15th, 1899.)

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The Geological History of Lake Superior.

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In the talk which I am about to give on the Geological History of Lake Superior I propose to endeavour to trace the origin and development of the lake itself rather than to sketch the geology of the surrounding country. The genesis of some of the great lakes, or rather of the depressions in the continent which they occupy, has been the subject of some investigation and of much discussion and speculation among geologists, but their researches and controversies have related mostly to the lower lakes, while but little has yet been written as to the geological history of Lake Superior. It was on this account, and because I have worked for many years on and around this inland sea and have paid some attention to this matter, that I have chosen it as the subject of my address to-night.

Before proceeding to speak of the basin of Lake Superior, I shall say a few words about the basins of the other great lakes, the origin of each of which has been similar to the others, but in some respects different from that of Lake Superior. Sir Andrew Ramsay and Sir William Logan supposed them to be due principally to glacial action; that is to say, that they had been scooped out of the rocks in which they lie, mainly by the denuding force of heavy and extensive masses of land ice. Although the eroding or excavating power of thick glaciers is very great, still it does not appear to have been sufficiently powerful to account for all that was formerly attributed to it. It has been pretty satisfactorily shown that during the glacial period their action in modifying the surface features consisted largely in the transportation of previously decomposed and loosened rock.

A former assistant of mine on the Geological Survey, Dr. J. W. Spencer, was, I think, the first to point out that the depressions now occupied by all the lakes east of Lake Superior represent the wide valleys or hydrographic basins of former rivers, more or less modified by subsequent glacial action, together with slight and widespread undulations or warpings of the crust of the earth. Although our lakes are so extensive

and present such a conspicuous figure on the maps, they are quite shallow relatively to their area, and as the surface of this part of the continent is so generally level, a very small amount of denudation and a very slight undulation in the land would suffice to produce the shallow depressions which they fill.

Before the advent of the glacial period a great part of North America stood at an elevation of 3,000 feet or more above its present level, and the disintegration and removal of the rocks due to rainfall alone, which was facilitated by the greater elevation, went on for a vast length of time. This is proved by the existence of long and deep river valleys, some of them running down from the central parts of the continent to the present sea coasts, and beyond them into the depths of the ocean. The old valley of the St. Lawrence can be traced for 800 miles. The ancient bed of the Hudson has been followed by soundings, from its present mouth, down the slope of the bottom of the ocean far out to sea. The cañon of the Saguenay, and those of the Grand or Hamilton and other rivers of Labrador, as well as the channels of many of the long straight lakes and river stretches in the Archæan country to the north and northwest of us, are due partly to atmospheric and aqueous erosion during a long geological period while the land stood at higher levels. It can be shown that the grade of the Mississippi from its source to the sea was much steeper formerly than now, the present modification or lowering of the slope amounting to some 3,000 feet. The valleys thus excavated guided, to a considerable extent, the movements of the great glaciers which ploughed the surface of hill and dale, excavating and carrying forward vast quantities of the softened surface rock, together with harder portions in the shape of fragments, boulders and pebbles, which together constitute our till or hard-pan and other deposits, collectively called drift. The general tendency of the glacial action would be to enlarge the main valleys of the preglacial surface and to fill up or modify the smaller ones.

The geological structure and the relative resisting powers of the rocks were the primary or fundamental causes which predetermined the location, direction, extent, etc., of the valleys and basins thus formed by the combined action of aqueous denudation and glacial action.

The theory of preglacial river-erosion as the main factor in originating the lake basins may apply to all of them with certain differences in each case. The soundings show the existence in the bottom of each, of deep channels resembling river valleys on the land traversing their beds and leading to former outlets now closed up by drift materials, but which

formerly drained these lakes or connected them with one another. We are indebted mainly to Professor J. W. Spencer for the discovery and location of these connecting channels. One of them, starting in Lake Michigan, runs eastward across the State of the same name, through the basin of Lake Huron to the northern extremity of the Indian Peninsula, thence down the bottom of Georgian Bay and across the neck of land to Lake Ontario. Another of these buried channels runs northward from Lake Erie to the western extremity of Lake Ontario. The basins of all the lower lakes are excavated in the softer portions of the almost horizontal palæozoic strata, so that their shapes and directions conform to some extent with the geological structure or arrangement of the strata. Lake Superior lies in a hollow almost surrounded by the primitive crystalline rocks. At one time it was probably filled with newer strata, which have been mostly removed by aqueous and glacial denudation; but small areas of those rocks still remain.

Lake Superior lies in the region of the general watershed or summit level of the continent east of the Rocky Mountains, although it is only 600 feet above the sea. From near its shores the water flows west to the Winnipeg basin, north to Hudson's Bay, and south to the Mississippi, while its own discharge is eastward to the St. Lawrence.

The drainage system, or catchment basin of Lake Superior proper, is consequently small, but it has a sort of extension or appendix in the basin of Lake Nipigon, which is really the uppermost of the Great Lakes of the St. Lawrence. This [illegible] f water measures eighty miles from north to south by fifty miles from east to west, with extensive bays on all sides. Its area is about half that of Lake Ontario, or between 3,000 and 4,000 square miles. Thirteen rivers and many brooks flow into it from various directions. One of its bays is only twenty-four miles from the nearest point of Lake Superior, and its surface has an elevation of 244 feet above the latter. The Nipigon river, which is the upward continuation of the St. Lawrence, is a clear-water stream and altogether the largest one flowing into Lake Superior. The larger number of the rivers and brooks falling into the great lake are darkly colored. Some of them look almost black as they enter its limpid water, the contrast being very striking. But the vegetable matter, to which the colour is due, soon becomes oxidized and disappears. There is a general absence of mud and also of dissolved mineral matter in the tributaries of Lake Superior, and hence its waters are not only singularly transparent, but also nearly chemically pure. The sounding lead has shown that the bottom of the Lake in nearly all parts consists of clay.

In tracing the origin of the basin of Lake Superior, we must go back to a very early period in the history of the solid earth. It appears to have begun with a depression in the original crust, even before the deposition of the oldest Huronian rocks, and probably before any water at all rested upon the heated surface of the globe. The great basin of Hudson's Bay is an example of a still larger depression in the first formed crust, which has persisted to the present day.

The vast Archæan region of North America, embracing perhaps one-third of its area, and which formed the nucleus of the continent around which the land has grown by the addition of one formation outside of another, has a general elliptical outline and extends from the north of Greenland in the far northeast to the State of Missouri in the southwest.

The depression of Lake Superior and that of Hudson's Bay and its connecting waters to the northward are within this ellipse. The earliest clastic deposits from the primeval sea might be looked for in these hollows and in the corresponding levels around the primitive nucleus of the continent, and hence, in these situations we find the Newer Laurentian and the Huronian systems largely developed and followed by the fossiliferous formations while the higher grounds or those more distant from these depressions as well as from the general periphere, consist almost entirely of the oldest gneiss which appear to be all modified from a granitic magma. The Huronian series, made up to a great extent of igneous rocks, are very largely developed to the south and west of Lake Superior in the States of Michigan, Wisconsin, Minnesota and Dakota, as well as throughout the country lying to the northwestern, northern and northeastern sides of the lake. During the succeeding Lower Cambrian period, the region of Lake Superior was the site of great outpourings of igneous matter, which formed the diorites, diabases, melaphyres, gabbros, amygdaloids, etc., of the Animikie and the Nipigon series. Between the Huronian and the older Cambrian periods, a vast interval of time elapsed, of which but little record has been left in the Lake Superior region. The upturned edges of the highly disturbed Huronian rocks were denuded down to a nearly level surface, and upon them were deposited the horizontal and undisturbed beds of the Animikie and Nipigon or the older Cambrian system, which have remained unaltered to the present day. The masses of granite of greater or less extent, which cut the Huronian and sometimes the Laurentian rocks around Lake Superior may have been erupted during this long interval, as we do not find them intersecting the Cambrian or any of the still newer strata, although they are themselves cut by dykes

similar to those which traverse the Huronian. Geographically these eruptive granites are scattered around the lake outside of the area of the Cambrian igneous overflows, or in other words they lie, in a general way, between this area and the vast region of primitive gneiss beyond. Some of these granitic masses are large and are elongated parallel to the present coast lines, such as the one called the Giant's range, lying back from the northwest shore in Northern Minnesota and the Thunder Bay District, some of those near Nipigon Bay, Otter Head, and thence eastward to Michipicoten River, and Pointe Brule, from which a wide mass runs inland.

The Nipigon or Keeweenian formation, consisting largely of the igneous rocks already mentioned, occupies the outermost large points and islands all around the lake, such as those of Nipigon Bay, Keeweenaw Point, Isle Royale, Michipicoten Island, Gargantua and Namainse,* and it is probable that the bed of the whole lake consists mostly of this formation. The dip of both the Nipigon and the underlying Animikie rocks on both sides is towards the centre or deeper parts of the lake. The lake-basin existed before these rocks were laid down and it is probable that their present dip is partly due to a gentle inward slope of the surface on which they were deposited whether as sediments or volcanic sheets, but the higher dips which they have now assumed are believed to be owing to the slow sinking or caving-in of the crust following the removal, from beneath the basin, of such vast quantities of igneous matter to form the sheets of greenstones in the Animikie and the amygdaloids, etc., of the Nipigon formation, of which only fragments remain at the present day.

Those portions of the shores of Lake Superior which are occupied by the Laurentian, Huronian and older Cambrian rocks are noted for being traversed by great numbers of dykes of various kinds of greenstones. The larger fissures, marked by these dykes, may at one time have allowed great quantities of molten matter to escape to form the trappean overflows of the Animikie and the amygdaloids, etc., of the Nipigon series. On the other hand, these rocks may have been derived mainly from volcanic orifices now covered by the lake or represented by the plutonic necks to be found among the Huronian strata.

In the report on my survey of Lake Nipigon in 1869, I have shown that the immense horizontal cappings of diorite forming the upper part of the Nipigon series around that sheet of water appear to have flowed in from the direction of Lake Superior.

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* Namainse, meaning the little sturgeon, is the proper spelling of this name, but it is generally incorrectly written, "Mamainse."

The central subsidence which has been referred to, ceased before the deposition of the Cambro-Silurian strata of the south shore, such as the red and grey sandstones about Grand Island, the Pictured Rocks and Sault Ste. Marie, as well as the small remaining patch of fossiliferous beds of Limestone Mountain on Keeweenaw Point, lying west of L'Anse, all of which retain the horizontal attitude of their original deposition.

It is to be noted that around Lake Superior, red sandstones of two formations come together, or nearly so, in different localities; and at one time they were confounded with one another and both supposed to be of the same age. The one set is associated with the Nipigon or Keeweenian formation while the other is newer. In the region of Keeweenaw Point their contact is not clearly seen, and there has been some discussion as to their relative ages. But here, as in other parts of the lake, the tilting of the one and the undisturbed condition of the other serve to distinguish them.

From what I have said, it would appear that in the earlier ages of the earth, or until the Cambro-Silurian period, the Lake Superior region was always one of volcanic activity. If we except the unaltered fossiliferous strata in the southeastern part, we shall see that in approaching Lake Superior as a centre from any point on the ancient crystalline rocks which everywhere else surround it, we have furthest out a great area of fundamental gneiss, followed by successive zones of igneous origin. The Huronian rocks, mainly of volcanic character, occupy large areas all around. Then come many masses of intrusive granite of various kinds. These are followed by greenstones of the Animikie formation and finally, inside of all the others, come the more recent amygdaloids, etc., of the Nipigon or Keeweenian formation. These zones are not complete or regular, but the above is the general order of their occurrence. This rude, concentric arrangement of different igneous rocks which become newer and newer as we approach the inner part, would indicate that there was here a deep-seated volcanic centre, dating back to very ancient geological times. The area of volcanic action had thus a great width in the early condition of the earth's crust, but it became more and more contracted as the world grew older and at length the active condition ceased altogether.

I have thus presented some of the fundamental geological reasons why the present site of Lake Superior was prepared to become a lake-basin, but between the stage in its history at which we have arrived and the next actual evidence as to how the basin was formed, there was a

long interval, during which we can only surmise what was going on. Cambro-Silurian rocks, forming part of the northern margin of the great area of these strata lying to the southward, occupy the shore of the lake from Marquette to the outlet, a distance of 130 miles, and farther south they are succeeded by the Devonian and Carboniferous systems in their regular order. Patches of Cretaceous rocks, resting on the Archæan, occur in Minnesota at no great distance west of the lake. It is therefore probable that this part of the continent was submerged throughout much, if not all, of the time up to about the commencement of the Tertiary period. During this period there must have been a very long interval of erosion, in which the land surface was deeply sculptured and the present inequalities to a great extent produced. After this, when the glacial period came on, the deeply decomposed surface was ploughed up and its materials were transported to greater or less distances. Thus its removal from one part of the land and its deposition on another would add to the inequalities of the surface and might deepen and extend the larger existing lake-basins very much, while it would be the means of creating innumerable smaller ones. On the glaciated surface of the crystalline rocks, great numbers of lakes now show at a glance what their history must have been. We see the glacial furrows and striæ descending into the rock-basins on the one side and emerging on the other, while heaps of boulders and drift material are left wherever they could find rest or shelter from the moving ice or where they may have been deposited by the final melting away of the glacier. A few of the lakes have been formed by the damming up of valleys and partial basins by moraines of drift, but the great majority of them are complete rock-basins. There seems to be no limit to the size of the basins which may be formed in this way, and if we extend our conception of the power and volume of these old continental glaciers and imagine them to have acted upon a deeply softened surface, there is no reason why we may not believe that the greatest of our lake-basins might have been excavated in this manner. It is a question of what is most probable. If, in addition to these processes, we take into consideration the slow undulation, tilting or warping of the crust of the earth, which is known to have been going on, and which is still in progress all over this part of the continent, we shall have no trouble in accounting for the existence of our great lakes. When we remember how slight is their depth in comparison with their area, we see how easily they could be formed on this extensive plain of the continent. To give you an idea of the insignificance of the actual depth of these great sheets of water as compared with their extent, let us construct a vertical section through Lake Huron from north to south on a natural

scale. If the horizontal distance be represented by one yard, we shall find it difficult to draw two lines on paper close enough together to show the difference between the surface and the bottom of the lake. In geological as well as engineering profiles we are accustomed to see the vertical measurements so greatly exaggerated that we are apt to overlook the true proportions.

To unscientific persons who have not given the matter a thought, it may be a surprise to learn that our great lakes with their present outlines and areas, and their existing outlets or connections with one another are all very new, geologically speaking. Indeed all lakes, whether great or small, and in whatever continent they may be situated, are necessarily unstable and transient even in their very existence, owing to the movements which are going on perpetually in the crust of the earth and which tend to either raise or lower their outlets—in the latter case tipping the water out—and partly to the fact that the discharging streams are constantly wearing their beds to lower levels.

The present great lakes of the St. Lawrence are only remnants lying in the deeper recesses of much larger ones which existed in comparatively recent times. There is plenty of evidence to show that in post-tertiary times a fresh water sea extended from the front of our Laurentian highlands southward to the Middle States, and that only a ridge west of Lake Superior separated it from another fresh-water sea which covered over all the lakes of the Winnipeg basin and also extended as one sheet, far up the low and level Saskatchewan and Red River valleys. The great valley of the Mississippi has been the site of numerous wide lakes, in the bottoms of which have been preserved the bones of a large number of species of curious and interesting mammals, all of which are now extinct. If the northern part of Hudson's Bay were raised a very little, and its southern part slightly depressed, so as to flood the low lands around it, we should have a fresh-water lake of unexampled extent, rivalling the Mediterranean Sea in area. It is possible that such a lake did really exist for a short time. Indeed the central part of our continent, all the way from the Rocky Mountains to the Appalachians and the Labrador Peninsula has been the region of the greatest lakes of the world in tertiary and post-tertiary times, and even their degenerate successors of the present day retain respectable proportions.

So far as I am aware, Professor Chapman, late of Toronto University, was the first to recognize the former extension of the great lakes in one sheet as the probable explanation of the phenomena of the superficial geology of the whole lake region and surrounding country.

A great part of the work of excavating the lake basins was therefore completed before the glacial period and at its close, the land, which had stood at a considerably higher level than at the present day, had been depressed somewhat below its present position, and the relative elevations of different parts had been slightly but sufficiently altered to check the flow of the waters as continuous river-courses, and to flood extensive tracts and form lakes much greater than even the present ones.

The wide river-valley forming the bottom of Lake Ontario, about 700 feet below the present surface of the lake, was not continuous with its present outlet by the St. Lawrence, but turned southward opposite to Oswego, and was continued in the valley of the Mohawk and Hudson. The rivers, whose branching valleys now form Lakes Huron and Erie, probably discharged from the west end of the latter into the old Mississippi, as these lakes are known to have done by the Wabash at the close of the glacial period. The ancient river of the valley of Lake Michigan probably flowed south into the old Mississippi, as the lake itself did, at the close of the glacial period, and as it will do again very soon. Lake Superior appears to cover two valleys of ancient erosion, one lying under the western part and the other under the main body of the lake. The bottom or deeper part of the former runs from Duluth, at the head of the lake in a very direct course to Black Bay, keeping quite close to the northwest side. The land along this side of the lake is high and bold, so that with the portion under water added, the total depth of the valley is 2,000 feet. The other valley has several main branches spreading over the remainder of the lake, but all apparently leading also to Black Bay. The pre-glacial discharge of the valleys which now hold Lake Superior was most probably by way of Black Bay, the valley of Black Sturgeon River, Lake Nipigon, and thence northeastward directly into the sea, or by way of an ancient river which traversed the site of Hudson's Bay when the continent stood at a higher level. In considering this question, it must be borne in mind that during the period referred to the relative levels of the land to the north and south were reversed, as compared with the present day.

There is a possibility that the ancient drainage of what is now the basin of Lake Superior was southward, perhaps by way of Train River, near Grand Island. We have thus seen that the advent of the glacial epoch found all the eastern part of the continent standing perhaps 3,000 feet higher than at present, with a very old eroded surface totally unlike the present one, and with an entirely different topography. There was a general scarcity of lakes and few or no waterfalls or rapids in the larger rivers, as all would be worn down to base levels.

In whole districts the general course of the streams was in the opposite direction from the present. Several great rivers, which existed then, are now entirely wiped out, and the whole topography is so changed that, looking at the map of the present day, their courses would not be suspected. Take, for example, that of the old St. Lawrence as mapped by Dr. Spencer, starting from the middle of Lake Michigan, crossing the land to Lake Huron, thence through Georgian Bay, then across country to Lake Ontario, from which it again crossed country to the Mohawk and on down the Hudson to the Atlantic coast, which was then far to the east of its present position. About the same time, as I have stated, Lake Superior may have discharged through Black Bay and Lake Nipigon into the sea to the north. The present round-about arrangement of the discharge of the great lakes, which however is only temporary, has a very unusual appearance from a topographical point of view. The pre-glacial drainage of the valleys which now form the bottoms of three lakes, running in the various directions I have indicated, would be more in accordance with what we might expect from the general contour of the country, so that it is not at all extraordinary that it followed these lines. In a paper read to the Royal Society of Canada a few years ago, I sketched the hypothetical course and the branching of a great pre-glacial stream which finally flowed into the north Atlantic along the bottom of what is now Hudson's Strait. and which was probably larger than any of the existing rivers of the world.

The glacial epoch was of long duration and in these latitudes it was broken by interglacial periods, each of which probably lasted for a great length of time, and during them the vegetation, which had been driven south, partially returned and must have given the country something of the appearance of the present day. Although the glacial conditions have finally retreated as far as Baffinland and Greenland, many of the trees of North America are still in the process of returning as far as possible towards their original home in the north. But we have not the time this evening to pursue this interesting topic. In a general way the climate of these latitudes since the disappearance of the continental glacier has never been better than at the present day, but in certain deposits of more recent date on the north side of Lake Superior, I have found evidence of a milder interval which may nevertheless have been some thousands of years ago.

As the very existence of our great lakes, as well as their former extensions, their successive relations to each other and their drainage

systems are all associated with the depression and subsequent elevation of the land, it will be in order for me here to say something of these movements. Geologists have not yet agreed as to what produced the glacial epoch—a unique event in the history of the earth—but they think the most probable cause of the depression of the northeastern part of the continent during and just following that epoch was the great weight of the mass of ice which had accumulated to a depth of one or two miles over a vast area. The oscillations of the land, as compared with the sea-level, which have always been going on in one part of the earth or another are mainly due to the shifting of the surface-load by its partial removal from one region to another through the agency of water, volcanic action, etc. The rocks, which appear to be quite rigid on the small scale are really not so, and on the large scale they yield slowly to pressure. The relatively small depression produced by this continental ice-sheet was less than might have been expected, and the rising of the land which is still going on, is the rebound, as it were, or the effort to regain its equilibrium after the load has been removed. Around any of our great lakes, one may easily observe abundant and distinct evidence of higher stages of the water in the form of terraces, old beaches, ridges, curving spits and other shore phenomena. They are found at many different levels around all the lakes. The principal ones at various heights may be connected so as to show that the water stood long enough at each of these heights to wear into the land and leave these permanent records. But a curious fact about the beaches and terraces is that in a northeasterly and southwesterly direction they are not horizontal but slope upwards in the former at a rate which is sufficient to be easily measured, amounting to from five inches to three feet or more per mile. This important circumstance was first noted by a Canadian writer in referring to the terraces around Georgian Bay about 50 years ago, but I have forgotten at this moment where I read about it. The changes in the elevation of numerous well-marked beaches around the various lakes have been determined throughout long distances by several well known geologists, among whom I may mention G. K. Gilbert, F. B. Taylor, Warren Upham, Frank Leverett and Professor W. C. Chamberlain of the United States and Drs. J. W. Spencer and A. C. Lawson of Canada, both formerly assistants of my own. The bearing of the line of maximum rise was easily found after the rate of increase in elevation had been ascertained along various lines forming greater or smaller angles with it and Professor Gilbert gives it as N. 27° E. for the lower lake region. If we look in the opposite direction along this line we would speak of the movement as a depression. We have seen, however, that it is really

a differential elevation towards the north-northeast, but the rate is not uniform and there may also be local warping of the crust.

Around the lakes of the Winnipeg basin, a similar phenomenon has been observed. On the western side of Lakes Manitoba and Winnipegosis, which were one sheet when the water was slightly higher, the ancient beaches are very well marked, and Mr. J. B. Tyrrell, formerly of our Geological Survey, has shown that in going northward they rise at the rate of about one foot per mile or 300 feet in the length of the two lakes.

Now lines drawn at right angles to the bearing of the maximum rise would represent isobases or axes along which there would be no change of level although the land might be rising to the northward or sinking to the southward.

The country is tolerably low and level about the outlets of all our lakes and there is no evidence of the former existence of any kind of obstruction to the outflow of the waters—not even of "ice-dams," which used to be convenient suppositions for getting over difficulties of this kind. Before the discovery of the earth movements, which have been referred to, there was thus great difficulty in accounting for the former extensions, higher levels, shifting of outlets and other changes to which we knew the lakes had been subject.

Around the northern shore of Lake Superior, Dr. A. C. Lawson has ascertained, by the spirit-level, the elevations at a considerable number of different localities of thirty-three of the most conspicuous of the terraces. These elevations range from near the present level up to more than 600 feet above it. In 1846, Sir William Logan described the remarkable set of distinct terraces at Les Ecrits or Terrace Bay near the mouth of Steel River or Schreiber, on the Canadian Pacific Railway, and Agassiz gives a picture of them in his "Lake Superior" published in 1851. Dr. A. C. Lawson ascertained that the highest water-mark in this vicinity was 418 feet above the present surface of the lake, but further west near the mouth of Arrow River he found terraces marking old beach lines up to 607 feet above the lake. If the water stood at any of these upper levels at the present day, there is no ground to the southward high enough to prevent it extending to the Gulf of Mexico. But if the sand and gravel in which these terraces are cut had been deposited by the sea, we would be pretty certain to find in them the remains of marine organisms, as we do in the post-glacial deposits of the province of Quebec. Fresh water, especially in a cold climate, produces few or no mollusks, and even if it did, their shells do not last as long as

those of marine species when embedded in sand or gravel. It is, therefore, probable that at the close of the glacial epoch, an enormous sheet of fresh water covered the whole region of the great lakes of the St. Lawrence and extended far to the south, and that it was drained away to the southward by a slightly greater elevation of the land in the north. Geologists have named this vanished sea Lake Warren.

After a time, the land to the south of the general basin of the great lakes had become dry, but all the water above Lake Ontario was united in one body, which included Lake Nipigon and flooded the land north of Georgian Bay as far as Lake Temiscaming. Dr. Spencer has named it Lake Algonquin and it discharged by the Trent valley into his Lake Iroquois which covered the site of Lake Ontario and the surrounding country and flowed out to the sea by the Mohawk valley.

When the water had fallen to within about 100 feet of the present level of Lake Superior, it remained united with Lakes Michigan and Huron as one sheet in three lobes discharging by way of Lake Nipissing and the Ottawa River. Mr. F. B. Taylor proposes the name Great Lake Nipissing for this former inland sea. The fact that a differential elevation of the land towards the north-northeast has been going on and is still in progress is proved by the undoubted southward inclination of the ancient beaches around the great lakes which succeed one another and together record a movement which was continuous through a great length of time, and also by other phenomena which I have observed in the northern part of the Province of Quebec and in the Labrador peninsula. But we are not dependent on the geological records alone to establish the existence of this movement in the crust of this part of the earth. Professor Gilbert has carefully investigated the readings of various gauges which were placed many years ago at different points on the American side of the lakes and he has found that, after eliminating all disturbing elements, they agree in showing a steady fall in the water towards the north and a corresponding rise towards the south, which amounts to about .42 of a foot per 100 miles per century. I am of the opinion that both the amount and rate of the uplift increase for a certain distance to the northward or until we reach the centre of the maximum height of the ice during the glacial period; and consequently around Hudson's Bay and in the Labrador peninsula the elevation is going on more rapidly than in our lake region. This is only what we might naturally expect if our theory of the cause be correct.

As a consequence of this tipping up, or canting of the lakes, their northern shores are shoaling, while their southern ones are flooding.

The quantity of water in the lake will be increasing or diminishing according to the position of the outlet. If we draw a straight line through the outlet of each lake at right angles to the line of uplift, this isobase will represent the axes along which its surface is being tilted and on it there will be no change of level, while the further we go from it to the north the greater will be the fall and the further to the south, the greater the rise. This isobase of Lake Superior runs from Sault Ste. Marie to a point on the northwest side near the international boundary line. Heron Bay is the most northern and Duluth the most southern part of the lake in reference to this line. At the above rate of tilting, Professor Gilbert calculates that the fall in the lake at the former place is five inches and the rise at the latter six inches per century, or a

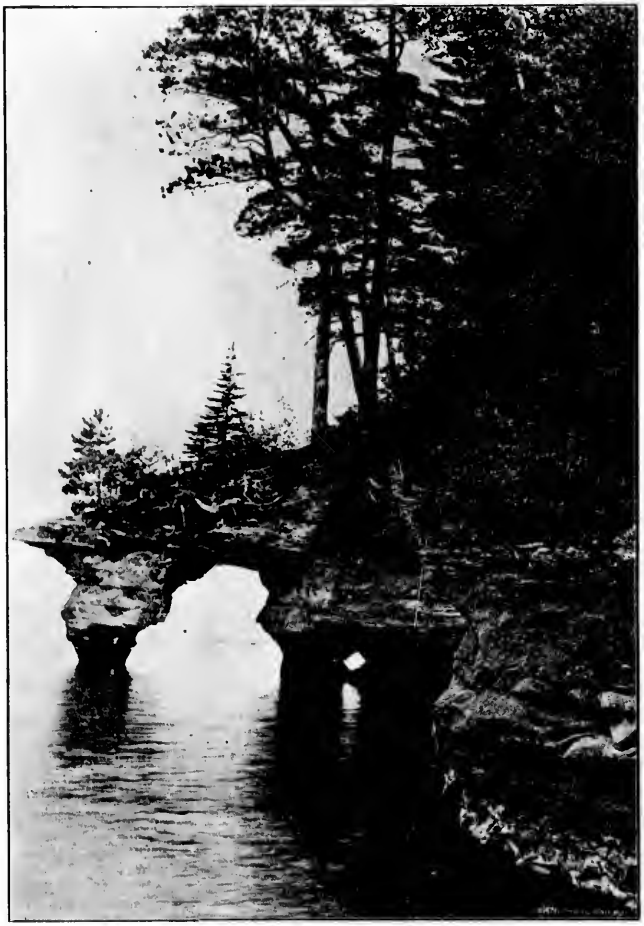
Modern Raised Beaches, Pointe Brulé, North Shore.

relative difference of nearly a foot per hundred years. This movement having been going on for a long time, the contrast in the appearance of the two sides of the lake is quite noticeable. On the north side, we see wide shores and many raised beaches, while on the south shore the lake is washing away the land or the waves are beating against the partly submerged cliffs and the coast has a generally drowned appearance.

The contrast between these two conditions is well brought out by the accompanying illustrations, one showing modern raised beaches on the north side and the other the rising water eating away the sandstone on the opposite shore.

Before closing I may say a few words in regard to a possible cause of

the driftless area to the south of Lake Superior in Wisconsin. The great extent and depth of the basin of Lake Superior, which, as we have seen, was in existence before the advent of the glacial period, lying across the course of the on-coming land ice, must have had an important



View near Ashland, South Shore, showing gradual submergence.

effect in checking its progress. This influence of a great depression would be much enhanced by the very considerable height of the land on the south side of the greater part of the lake.

Along the eastern part of the south shore of Lake Superior, glacial striæ are not seen, the rocks being mostly buried under sand and other superficial deposits. The general trend of the striæ is increasingly deflected to the westward of south as we proceed towards the western extremity of the lake.

The drift or till which is very heavy towards the western part of the south side of Lake Superior is all red, owing to the colour of the sandstones, marls, etc., from which it has been derived, to the east and in the bottom of the lake. Around Thunder Bay and at other places on the northwest side of the lake, the glacial grooving has a westerly course and the debris of the red marl of the lake-basin has been carried out west over the land for a distance of fifty miles or more. In many places on the east shore, the striæ run up from beneath the water and continue inland with an easterly bearing. It is well known that the peculiar form of red jasper conglomerate, which, as far as we are aware, is found *in situ* only at the north end of Goulais Bay and north of the St. Mary's River, has been carried east with the drift all along the north shore of Lake Huron, from which it has been subsequently moved south and southwest by a more recent and probably lighter system of glaciation. Along the west side of Lake Michigan the striæ are reported to have a course west of south. The ice-sheet which produced the striæ either passed the side of the driftless area or did not extend to it. We may therefore conclude that to whatever extent the basin of Lake Superior was deepened or enlarged by glacial action the excavated material was carried mainly to the west and east and failed to reach the driftless area of Wisconsin.